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14. ABSTRACT The most recent results achieved:
We showed that electron spin flips are dominated by nuclear interactions and are slowed by several orders of magnitude when a magnetic field of a few millitesla is applied.
We demonstrated coherent control of a quantum two-level system based on two-electron spin states in a double quantum dot allowing state preparation, coherent manipulation, and projective read-out.
We showed how realistic charge manipulation and measurement techniques, combined with the exchange interaction, allowed for the robust generation and purification of four-particle spin entangled states in electrically controlled semiconductor quantum dots.
We developed an architecture for quantum computation using electrically controlled semiconductor spins.
We described a novel method for precise estimation of the nuclear spin polarization of a quantum dot via manipulation and measurement of a single electron spin trapped within the

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“Novel Techniques for Quantum State Manipulation in Mesoscopic Systems”

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Statement of Problem Studied

Quantum information and computation form one of the main current scientific and technological challenges. Proposals exist for a variety of physical systems and initial results have already been obtained. However, the practical implementation of scalable quantum computation requires coherent manipulation of a large number of coupled quantum systems. This is an extremely difficult task that is believed to be well beyond the possibilities offered by any presently known technologies. We propose to address this outstanding problem by developing a set of novel techniques that could potentially facilitate implementation of scalable quantum processing.

Two strong areas studying quantum information and computation are quantum optics and mesoscopic electronics. The key idea of the present project is to combine the conceptual advantages of well-developed quantum optical approaches with the immense technological capabilities associated with solid-state mesoscopic systems. To this end a team is formed for this proposal with theoretical and experimental physicists from both areas with close support from the computer science community.

The building blocks for this proposal are quantum dot devices. Quantum dots are ultra-small, solid state transistors with quantum mechanical properties. The technological state-of-the-art of quantum dot devices presently includes: well-defined and controlled quantum eigenstates (analogous to atomic orbitals); controlled superposition of eigenstates of coupled quantum dots; inclusion of quantum dots in an interference-ring structure to demonstrate coherence; and a control over both the charge as well as the spin properties of electrons confined to quantum dots. An important advantage for the use of quantum dots as building blocks for a quantum circuit is that its technology is based on the successful silicon-based chip technology. One can even envision an optimized on-chip circuit consisting of silicon transistors and coherently coupled quantum dots.

We here propose to develop theoretically and probe experimentally new techniques that allow for a) strong, coherent and potentially scalable coupling between quantum dots separated by distances much larger than the dot size using capacitive coupling as well as on-chip waveguides; b) coherent communication of quantum information between the dots on the chip via electron exchange and ballistic transport. The principal goal of the proposed research is to determine to what extent these potentially scalable systems can be built and probed under realistic experimental conditions.

Summary of most important results

Scientific Progress and Accomplishment

We have identified and analyzed the effects of nuclear spins as one of the main decoherence mechanisms for electron spin qubits. We have suggested and analyzed several techniques to greatly improve these coherence properties by means of quantum bit manipulation. Specifically, we show that electronic spin coherence can be reversibly mapped onto the collective state of the surrounding nuclei. The coherent transfer can be efficient and fast and it can be used, when combined with standard resonance techniques, to reversibly store coherent superpositions on the time scale of seconds. This method can also allow for "engineering" entangled states of nuclear ensembles and efficiently manipulating the stored states. We investigated the feasibility of this method through a detailed analysis of the coherence properties of the system

We developed a unified description of cooling and manipulation of a mesoscopic bath of nuclear spins via coupling to a single quantum system of electronic spin (quantum bit). We showed that when cooling is accomplished via coupling to quantum bit degrees of freedom, the bath rapidly saturates and ends in special, non-thermal states of a nuclear ensemble. Although such states of the spin bath ("dark states") generally have a very low degree of polarization and purity, their symmetry properties make them a valuable resource for coherent manipulation of quantum bits. Specifically, we showed that the dark states of nuclear ensembles can be used to dramatically suppress decoherence and to provide a robust, long-lived quantum memory for qubit states.

We proposed an electrodynamic mechanism for coherent, quantum mechanical coupling between spacially separated quantum dots on a microchip. The technique is based on capacitive interactions between the electron charge and a superconducting transmission line resonator, and is closely related to cavity quantum electrodynamics. We investigated several potential applications of this technique which have varying degrees of complexity. In particular, we demonstrated that this mechanism allows design and investigation of an on-chip double-dot microscopic maser. Moreover, the interaction may be extended to couple spatially separated electron spin states while only virtually populating fast-decaying superpositions of charge state. This represents an effective, controllable long-range interaction, which may facilitate implementation of quantum information processing with electron spin qubits, and potentially allow coupling to other quantum systems such as atomic or superconducting qubits.

We proposed a technique that enables a strong, coherent coupling between isolated neutral atoms and mesoscopic conductors. The coupling is achieved by exciting atoms trapped above the surface of a superconducting transmission line into Rydberg states with large electric dipole moments that induce voltage fluctuations in the transmission line.

Using a mechanism analogous to cavity quantum electrodynamics, an atomic state can be transferred to a long-lived mode of the fluctuating voltage; atoms separated by millimeters can be entagled; or the quantum state of a solid state device can be mapped onto atomic or photonic states.

We have demonstrated the detection of non-symmetrized current fluctuations at high-frequency (5-90 GHz) using a superconductor-insulator-superconductor tunnel junction. By coupling this noise detector on-chip to a quantum device, we measured high-frequency noise as demonstrated for a Josephson junction. This scheme is then used to detect the current fluctuations arising from coherent charge oscillations in two-level systems. The detection of frequency-resolved quantum noise is demonstrated for the superconducting charge qubit. A narrow band peak is found in the spectral noise density at the frequency of the coherent charge oscillations.

We have fabricated circuits of double quantum dot (DQD) devices in a configuration where one DQD is coupled capacitively to a second DQD. Each DQD can be separately tuned and separately measured, also independent of the properties of the other DQD. The two DQD’s are strongly coupled and, strictly speaking, they can not be treated as independent quantum systems. This integrated quantum system will be used for transferring quantum states from the left to the right. Currently, experiments have been performed where one side has been current biased, thereby inducing non-equilibrium current fluctuations. The effect of these fluctuations on the other side has been measured. The advantage of this setup is that the near vicinity of the two devices allows for coupling with a very high frequency bandwidth (~1 THz). The results, so far, demonstrate orbital excitations on the right-side quantum dots as a result of high frequency fluctuations on the left side.

We have demonstrated the non-invasive measurement of a double quantum-dot system that allows the hybridization of states between the two dots, due to tunneling to be read out quantitatively, using non-invasive capacitive sensors. This work also develops the theory of charge sensing of a two-level system, and compares theory and experiment. Excellent agreement between theory and experiment was obtained, allowing the tunneling rate to be extracted from the fit. It is worth noting that this technique for measuring tunneling represents the state of the art for measuring the tunneling rate in a double dot. The previously established method is considerably less accurate and more difficult.

We proposed and analyzed a technique for quantum information processing based on localized ensembles of nuclear spins. A qubit is identified as the presence or absence of a collective excitation of a mesoscopic ensemble of nuclear spins surrounding a single quantum dot. All single and two-qubit operations can be effected using hyperfine interactions and single-electron spin rotations, hence the proposed scheme avoids gate errors arising from entanglement between spin and orbital degrees of freedom. Ultra-long coherence times of nuclear spins suggest that this scheme could be particularly well suited for applications where long lived memory is essential.

We demonstrated experimentally an electrical single-shot measurement of single electron spin in gate-controlled a quantum dot. Spin to charge conversion has been used to accomplish this goal.

We demonstrated electron spin rotations induced by nuclear spins in a single electron gate controlled quantum dot. We showed that theses spin flips can be enhanced or suppressed by tuning appropriate external magnetic field. The experimental results are in excellent agreement with theoretical predictions. Using an isolated GaAs double quantum dot defined by electrostatic gates and direct time domain measurements, we investigated in detail spin relaxation for arbitrary splitting of spin states. Here we showed that electron spin flips are dominated by nuclear interactions and are slowed by several orders of magnitude when a magnetic field of a few millitesla is applied. These results have significant implications for spin-based information processing[12].[Nature, 435, 7044 (2005]

We demonstrated coherent control of a quantum two-level system based on two-electron spin states in a double quantum dot allowing state preparation, coherent manipulation, and projective read-out. These techniques are based on rapid electrical control of the exchange interaction. Separating and later recombining a singlet spin state provided a measurement of the spin dephasing time, $T_2^* \sim 10$ ns, limited by hyperfine interactions with the GaAs host nuclei. Rabi oscillations of two-electron spin states were demonstrated, and spin-echo pulse sequences were used to suppress hyperfine-induced dephasing. Using these quantum control techniques, a coherence time for two-electron spin states exceeding 1 μs was observed. [Science, in press; Online Science Express published Sept. 1, 2005]

We showed how realistic charge manipulation and measurement techniques, combined with the exchange interaction, allowed for the robust generation and purification of four-particle spin entangled states in electrically controlled semiconductor quantum dots. The generated states were immunized to the dominant sources of noise via a dynamical decoherence-free subspace; all additional errors were corrected by a purification protocol. This approach may find application in quantum computation, communication, and metrology. [Phys.Rev.Letters, 94, 236803 (2005)]

We developed an architecture for quantum computation using electrically controlled semiconductor spins by extending the Loss--DiVincenzo scenario and by combining an actively protected quantum memory, long-distance coupling mechanisms, and modular control circuitry. Our approach was based on a recently demonstrated encoding of qubits in long-lived two-electron states, which immunizes from the outset against the dominant error from hyperfine interactions. We developed a universal set of quantum gates compatible with active error suppression for these encoded qubits. To circumvent the unfavorable error thresholds for systems with only nearest neighbor interactions, we described an effective long range interaction between the qubits by controlled electron transport. This approach yielded a scalable architecture with realistic error thresholds for fault tolerant operation, consistent with present experimental parameters. [submitted to Nature Physics(2005)]

We described a novel method for precise estimation of the nuclear spin polarization of a quantum dot via manipulation and measurement of a single electron spin trapped within the dot. Our approach required a minimal number of electron spin measurements for a given precision. We considered applications such as reducing the electron spin dephasing due to nuclei and increasing the fidelity of nuclear-spin-based memory, and discussed the performance under realistic conditions.[quant-ph/0508144 (2005)]

Listing of all publications and technical reports supported under the grant

Period 2002-July 9, 2005

(a) Papers published in peer-reviewed journals

Papers acknowledging the ARO: #1, 2, 6, 11, 14, 16, 18, 21, 23, 26, 41-45.

1. J.M. Taylor, H.-A. Engel, W. Dür, P. Zoller, A. Yacoby, C.M. Marcus, M. D. Lukin, “Fault-tolerant architecture for Quantum Computation Using Electrically Controlled Semiconductor Spins,” submitted to Nature Physics (2005)

2. G. Giedke, J.M. Taylor, D. D’Alessandro, M.D. Lukin, A. Imamoglu, “Scheme for Quantum Measurement of the Nuclear Spin Polarization in Quantum Dots,” quant-ph/0508144, (2005)

3. A. Andre, M.D. Eisamann, R.L. Walsworth, A.S. Zibrov, M.D. Lukin, “Quantum control of light using electromagnetically induced transparency,” Journal of Physics B, **38**, S589-S604 (2005)

4. E. Altman, A. Polkovnikov, E. Demler, B. Halperin, M.D. Lukin, “Superfluid-insulator transition in a moving system of interacting bosons,” cond-mat/0411047, Phys.Rev.Lett., **95**, 020402 (2005)

5. A. Polkovnikov, E. Altman, E. Demler, B. Halperin, M.D. Lukin, “Decay of a superfluid currents in a moving system of strongly interacting bosons,” cond-mat/0412497, Phys.Rev.A, **81**, 063613 (2005)

6. J.M. Taylor, W. Dur, P. Zoller, A. Yacoby, C.M. Marcus, M.D. Lukin, "Solid-state circuit for spin entanglement generation and purification," cond-mat/0503255 v1, Phys.Rev.Lett, 94, 236803 (2005)

7. A.S. Sorensen, E. Demler, M.D. Lukin, "Fractional quantum Hall States of atoms in optical lattices," cond-mat/0405079 v2, Phys.Rev.Lett, **94** 086803/1-4 (2005)

8. A. André, M. Bajcsy, A.S. Zibrov, M.D. Lukin, "Nonlinear optics with stationary pulses of light," quant/ph/0410157, Phys.Rev.Lett., **94**, 063902/1-4 (2005)

9. D.-W. Wang, M.D. Lukin, E. Demler, "Engineering superfluidity in Bose-Fermi Mixtures of Ultracold Atoms," cond-mat/0410494, Phys.Rev.A, in press (2005)

10. M. D.Eisaman, L.Childress, A. André, F. Massou, A. S.Zibrov, and M. D.Lukin, "Shaping quantum pulses of light via coherent atomic memory," Phys.Rev.Lett, **93**, 233602 (2004)

11. A. Polkovnikov, E. Altman, E. Demler, B.I. Halperin, M.D. Lukin, "Decay of super-currents in condensates in optical lattices," cond-mat/0504300, Journal of Superconductivity, **17**, 577 (2004)

12. A. Imambekov, M.D. Lukin, E. Demler, "Magnetization plateaus for spin-one bosons in optical lattices: Stern-Gerlach experiments with strongly correlated atoms," cond-mat/0401526, Phys.Rev.Lett, **93**, 120405, (2004)

13. L. Mathey, D.-W. Wang, W. Hofstetter, M. D. Lukin, E. Demler, "Luttinger liquid of polarons in one-dimensional boson-fermion mixtures," quant-ph/0401151, Phys.Rev.Lett, **93**, 120404, (2004)

14. E. Altman, E. Demler, and M.D. Lukin, "Probing many-body states of ultra-cold atoms via noise correlations," cond-mat/0306226, Phys.Rev.A, **70**, 013603, (2004)

15. A. André, A.S. Sørensen, M.D. Lukin, "Stability of atomic clocks based on entangled atoms," quant-ph/0401130, Phys.Rev.Lett, **92**, 230801, (2004)

16. L.I. Childress, A. S. Sørensen, M. D. Lukin, "Mesoscopic Cavity Quantum Electrodynamics with Quantum Dots", quant-ph/0309106, Phys. Rev. A **69**, 042302, (2004)

17. D.E. Chang, Jun Ye, M. D. Lukin, "Controlling dipole-dipole frequency shifts in a lattice-based optical atomic clock," quant-ph/0308068, Phys.Rev.A, **69**, 023810, (2004)

18. A.S. Sørensen, C.H. van der Wal, L. Childress, M.D. Lukin, "Capacitive coupling of atomic systems to mesoscopic conductors," quant-ph/0308145, Phys.Rev.Lett., **92**, 063601, (2004)

19. Daw-Wei Wang, Mikhail D. Lukin, Eugene Demler, "Disordered Bose-Einstein Condensates in Quasi One-Dimensional Magnetic Microtraps," cond-mat/0307402, Phys.Rev.Lett, **92**, 076802, (2004)

20. M. Bajcsy, A. S. Zibrov, M. D. Lukin, "Stationary pulses of light in an atomic medium," Nature **426**, 638, (2003)

21. J.M. Taylor, A. Imamoglu, M.D. Lukin, "Controlling a mesoscopic spin environment by quantum bit manipulation," cond-mat/0308459, Phys.Rev.Lett , **91**, 246802, (2003)

22. S. F. Yelin, V. A. Sautenkov, M. M. Kash, G. R. Welch, M. D. Lukin, "Nonlinear optics via double dark resonances," quant-ph/0306147, Phys.Rev.A, **68**, 063801, (2003)

23. Ehud Altman, Walter Hofstetter, Eugene Demler, Mikhail D. Lukin, " Phase diagram of two-component bosons on an optical lattice," cond-mat/0306683, New Journal of Physics, special issue on "Quantum gases", **5**, 113, (2003)

24. A. Imambekov, Mikhail Lukin, Eugene Demler, "Spin Exchange Interactions of Spin-One Bosons in Optical Lattices: Singlet, Nematic and Dimerized Phases," cond-mat/0306204, Phys.Rev.A, **68**, 063602, (2003)

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26. J.M.Taylor, C.M.Marcus, and M.D.Lukin, "Long-lived memory for mesoscopic quantum bits," cond-mat/0301323, Phys.Rev.Lett, **90**, 206803, (2003)

27. C. van der Wal, M. D. Eisaman, A. André, R. L. Walsworth, D. F. Phillips, A. S. Zibrov and M. D. Lukin, "Atomic memory for correlated photon states," (2003) Science, **301**, 196; (published online in Science Express on May 22, 2003)

28. M.D. Lukin, "Colloquium: Trapping and manipulating photon states in atomic ensembles," Rev.Mod.Phys., **75**, 457 (2003)

29. W. Hofstetter, J.I. Cirac, P. Zoller, E. Demler, and M.D. Lukin, "High-temperature superfluidity of fermionic atoms in optical lattices," cond-mat/0204237, Phys.Rev.Lett, **89** 220407 (2002)

30. A. André, and M.D. Lukin, "Manipulating Light Pulses via Dynamically Controlled Photonic Bandgap," quant-ph/0205072, Phys.Rev.Lett., 89, 143602 (2002)

31. R. Cote, V. Kharchenko, and M.D. Lukin, "Mesoscopic molecular ions in Bose-Einstein condensates," quant-ph/0112113, Phys.Rev.Lett., 89 093001 (2002)

32. A. André, L.M.Duan, and M.D.Lukin, "Coherent Atom Interactions Mediated by Dark-State Polaritons," quant-ph/0107075, Phys.Rev.Lett., 88, 243602 (2002)

33. A. André and M.D. Lukin, "Atom correlations and spin squeezing near the Heisenberg limit: finite system size effects and decoherence," quant-ph/0112126, Phys.Rev.A, 65, 053819 (2002)

34. R. Walsworth, S. F. Yelin, and M. D. Lukin, "The story behind "light stopping," Optics and Photonics News, page 51 May (2002)

35. A.S. Zibrov, M. D. Lukin, L.Hollberg, and M.O.Scully, "Efficient Frequency Up-conversion in Resonant Coherent Media," Phys.Rev.A, 051801 (2002)

36. A. Mair, J. Hager, D. Phillips, R. Waslworth, and M. D. Lukin, "Phase Coherence and Control of Stored Photonic Information," quant-ph/0108046, Phys.Rev.A., 65 031802 (2002)

37. M. Fleischhauer and M. D. Lukin, "Quantum memory for photons: Dark-state polaritons," Phys. Rev. A 65, 022314 (2002)

(b) Papers published in non-peer-reviewed journals or in conference proceedings

38. C. van der Wal, M. D. Eisaman, A. S. Zibrov, A. André, D. F. Phillips, R. L. Walsworth, and M. D. Lukin, "Towards non-classical light storage via Raman scattering in atomic vapor," Proceedings of SPIE "Fluctuations and Noise", vol. **5115**, 236 (2003)

39. M.D. Lukin, A. Andre, M. D. Eisaman, M. Hohensee, D. F. Phillips,C. H. van der Wal, R. L. Walsworth, A. S. Zibrov, "Toward Manipulating Quantum Information with Atomic Ensembles," Proceedings of ICAP-2002, page 231, World Scientific (2002)

40. J. Hager, A. Fleischhauer, A. Mair, D. F. Phillips, R. L. Walsworth, and M. D. Lukin, "Photonic information storage and quantum information processing in atomic ensembles," Proceedings of ICOLS XV, page 228, World Scientific (2002)

(c) Papers presented at meetings, but not published in conference proceedings

Colloquia & Seminars

1. Invited talk at Quantum Metrology MURI Kick-off, Boulder, CO June 2005
2. Invited talk at Slow Light Review, Destin, FL, May 2005
3. Invited talk at Yale University, Department of Physics Colloquium, New Haven, CT, February 2005
4. Invited talk at the Weizmann Institute of Science, Rehovot, Israel, February 2005
5. Invited talk at the University of Minnesota, September 2004, Minneapolis, MN
6. Invited talk at the University of Brazil, August 2004, Brasilia, Brazil
7. Invited talk at Stanford University, July 2004, Stanford, CA
8. Physics Colloquium, JILA and Physics Department, University of Colorado, Boulder, CO, April 2004
9. Invited talk at the Physics Colloquium, Princeton University, Princeton, NJ, March 2004
10. Condensed Matter Physics Seminar, Stanford University, Stanford, CA, Feb 2004
11. Physics & Applied Physics Colloquium, Stanford University, Stanford, CA, Feb 2004
12. Physics Colloquium, University of Toronto, Toronto, Canada, Sept 2003
13. Quantum computing program review, Nashville, TN, August 2003
14. “Chez Pierre ”Condensed Matter Physics Seminar, MIT, Cambridge, MA Feb. 2003
15. Atomic and Optical Physics Colloquium, University of Michigan, Ann Arbor, MI, Jan 2003

16. Physics Department Colloquium, University of Connecticut, Storrs, CO, April 2002

17. Physics Department Colloquium, University of Wisconsin, Madison, WI, April 2002

18. Special Optics Colloquium at University of Erlangen Nurnberg, Erlangen, Germany, April 2002

Invited Conference Presentations

1. Invited talk on Control and Manipulation of Quantum Systems, Ascona Switzerland, Monte Verita 2005, July 2005

2. Invited talk at Quantum Communications Research Conference, Denver, CO, June 2005

3. Invited talk at Quantum Physics of Nature/QIPC 2005, Vienna, Austria, May 2005

4. Invited talk at the Gordon Research Conference: Quantum Information Science, Ventura, CA, March 2005

5. Invited talk at the French-Israeli Symposium on Non-Linear and Quantum Optics (Frisno-8), Ein Bokek, Israel, February 2005-03-02

6. Invited talk at Quantum Information (QUIST) fall review, November 2004, Scottsdale, AZ

7. Invited talk at Quantum Computing Program Review, August 2004, Orlando, FL

8. Invited talk at Slow Light Conference, August 2004, Washington, DC

9. Lecture series at the University of Boulder Summer School on quantum coherence in atomic and condensed matter systems, July 2004, Boulder CO

10. Invited talk at the University of Michigan, June 2004, Ann Arbor, MI,

11. Invited talk at the Division of atomic, molecular and optical physics conference, May 2004, Tucson, AZ

12. Plenary talk at the 34th Colloquium on The Physics of Quantum Electronics, January 2004, Snowbird, UT.

13. Invited talk at the DARPA QUIST program meeting, Nov 2003, Orlando, FL

14. Invited talk at the Stanford MURI 2003 kickoff meeting, Oct 2003, Stanford, CA

15. Invited talk at the Packard Foundation Reunion, Sept 2003, Vancouver, Canada

16. Invited talk at the Gordon research conference on nonlinear optics, July 2003, New London, NH

17. Keynote talk at the European Quantum Electronics Conference, EQEC 2003, June 2003, Munich, Germany

18. Invited talk at the Gordon research conference on atomic physics, June 2003, Tilton, NH

19. Invited talk at the Quantum Electronics and Laser Science Conference, CLEO/QELS 2003, June 2003, Baltimore, MD

20. Invited talk at the APS meeting of Division of Atomic and Molecular Physics, DAMOP 2003, May 2003, Boulder CO

21. Invited talk at the Gordon research conference on quantum in formation, March 2003, Ventura, Ca

22. Invited talk at the Innsbruck quantum optics conference, Feb. 2003, Obergugl, Austria

23. Invited talk at the MIT workshop on quantum control, Oct. 2002, Cambridge, MA

24. Invited talk at the NSF workshop on new opportunities in materials theory, Oct. 2002, Wash., DC

25. Invited talk at the annual meeting of OSA 2002, Oct. 2002, Orlando, FL

26. Invited talk at the New Laser Science Conference 2002, Sept 2002, Orlando, FL

27. Invited talk at the ARO/NSA/ARDA quantum computing program meeting, August 2002, Nashville, TN

28. Invited talk at the ICAP 2002, August 2002, Cambridge, MA

29. Invited talk at the IQEC 2002, June 2002, Moscow, Russia

30. Invited talk at the College de France Quantum Optics Symposium, June 2002, Paris, France

31. Invited talk at the APS meeting of Division of Atomic and Molecular Physics,

DAMOP 2002, May 2002, Williamsburg

(d) Manuscripts submitted, but not published

41. J.R. Petta, A.C. Johnson, J.M. Taylor, E.A. Laird, A. Yacoby, M.D. Lukin, C.M. Marcus, M.P. Hanson, A.C. Gossard, "Coherent manipulation of coupled electron spins in semiconductor quantum dots," Science in press, Science Online Express (2005)

42. D.E. Chang, A.S. Sorensen, P.R. Hemmer, M.D. Lukin, "Cavity quantum electrodynamics with surface plasmons," quant-ph/0506117 v1, (2005)

43. L. Childress, J.M. Taylor, A.S. Sorensen, M.D. Lukin, "Fault-tolerant quantum repeaters with minimal physical resources, and implementations based on single photon emitters, " quant-ph/0502112, submitted to Phys.Rev.A. (2005)

44. L. Childress, J.M. Taylor, A.S. Sorensen, M.D. Lukin, "Fault-tolerant quantum communication based on solid-state photon emitters," quant-ph/0410123, submitted to Phys.Rev.Lett. (2004)

45. J.M. Taylor, G. Giedke, H. Christ, B. Paredes, J.I. Cirac, P. Zoller, M.D. Lukin, and A. Imamoglu, "Quantum information processing using localized ensembles of nuclear spins," cond-mat/0407640v2, submitted to Phys.Rev.Lett., (2004)

(f) Book Chapter

46. L. Childress, M. Eisaman, A. Andre, F. Massou, A. Zibrov, M. Lukin, "Towards quantum control of light: shaping quantum pulses of light via coherent atomic memory" to be published in "Decoherence, Entanglement and Information Protection in Complex Quantum Systems," NATO Science Series Volume 2, Springer/Kluwer Academic (2005)

List of all participating scientific personnel

Note advanced degrees earned while employed on the project

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Gurudev Dutt
Dimitry Petrov
Anatoli Polkonikov
Andre Sorensen
Casper van der Wal
Daw-wei Wang

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Darrick Chang
Lilian Childress
Matthew Eisaman
Mohammad Hafezi
Michael Hohensee
Aryesh Mukherjee
Jacob Taylor
Saijun Wu

Undergraduate Students
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Sidharth Shenai

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